Illustration by Mike Avitabile

My coherence is better in some measurements than others when impact testing. Am I doing something wrong?
There are definitely some issues to discuss here.

OK – so this yet another area of measurement quality that needs to be discussed. Impact testing is by far the most common and most popular of the approaches for obtaining frequency response functions for the description of a structural system. The impact test is a very economical approach for frequency response testing. In addition, impact testing is very easy to setup and is extremely portable for field testing. Due to the ease with which measurements can be made, impact testing is widely used in many industries and applications.

But there are a wide range of issues that need to be recognized when performing impact testing. Some of these relate to double impacts, pre-trigger delay, high peak voltages compared to overall RMS level of the signal, nonlinear systems, etc. Some of these are commonly cited "areas of concern" when impact testing. These often become the stated reasons why impact test results may have coherence values that are not as acceptable as may be desired. But these may not be the only reasons – one very important consideration that I would like to discuss in this article is the effect of impact location on the resulting frequency response function and its coherence.

When performing impact testing, the input impact location can have a very significant effect on the resulting frequency response function. And this can be seen in the coherence function measured for each set of averaged data. First, let's take a set of measurements where care is exercised in the impact location during the test to show a very good high quality measurement. Then some "less than perfect" impact measurements will be made on the same structure to show the degradation of the coherence.

The structure is a very simple structure with what are expected to be some very good measurements. A typical impact measurement is going to be made for the frequency response function at the drive point on the structure. Sampling parameters are selected such that the input force and response acceleration are totally observed signals within one sample record of data. This eliminates the need for any window functions on the input or output signals measured.

The measured frequency response (lower trace) and coherence (upper trace) are shown in Figure 1. Notice that the frequency response function appears to be a very good measurement and the coherence is very good for this measurement. The coherence for most of the frequency range is extremely close to one. The coherence has a slight dip in antiresonant regions but is not a problem for this measurement. (Note that drops in the coherence in antiresonant regions are expected due to the fact that the structure has no response at these frequencies and therefore the response of the system is not coherently related to the measured input signal.)

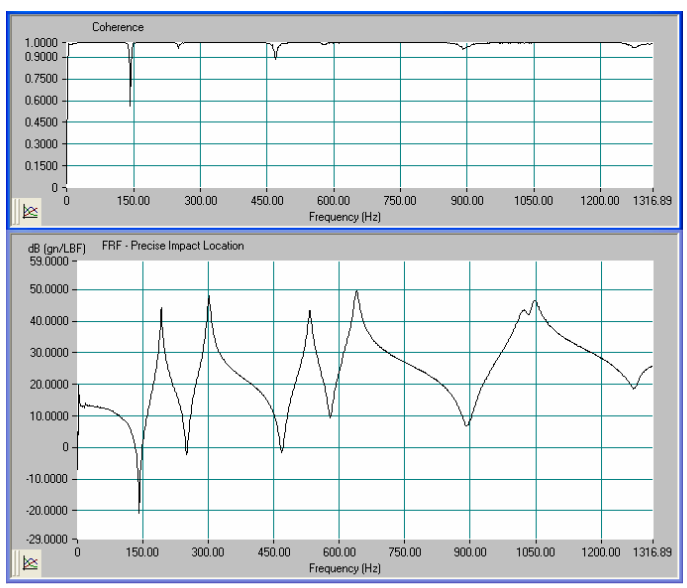

Figure 1 – FRF & Coherence for a Well Controlled Impact

Now in that first measurement, extreme care was exercised to assure that each average was the result of an impact at the same location in the same direction. This is a very important concern when impact testing.

To illustrate what happens where this care is not exercised, a measurement is made where each average is intentionally made within a region that is very close to the desired input location but there is some slight variation in the actual input location. With the same number of averages, the frequency response (lower trace) and coherence (upper trace) are shown in Figure 2 for this measurement where there is some variation for each impact location. While the frequency response function looks reasonable, the coherence is seen to have some significant degradation across the entire frequency range. While the coherence is acceptable in the immediate region of the peaks of the frequency response function, overall the coherence is poor.

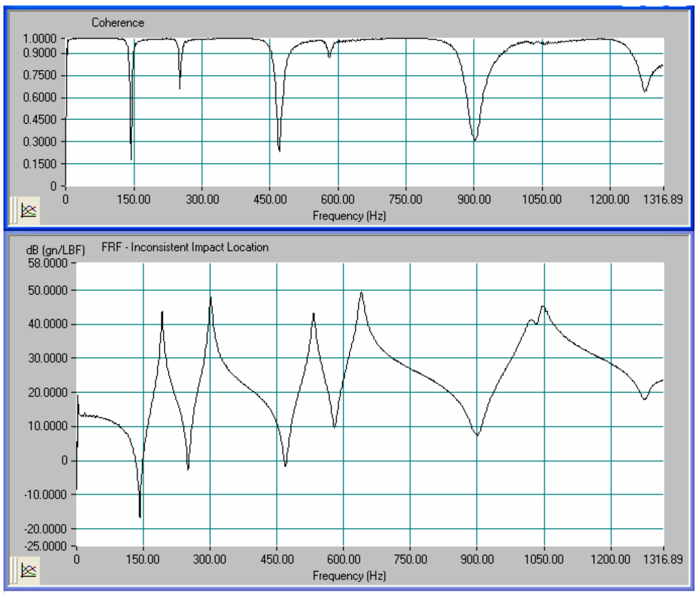

Figure 2 – FRF & Coherence for a Poorly Controlled Impact

The coherence is most significantly affected in the antiresonant regions of the frequency response function. This is due to the fact that while resonances are global characteristics of a system, the antiresonant regions are absolutely not global in character at all. The antiresonant regions are highly dependent on the particular input-output measurement location. Because care was not exercised during the impact test to assure than all impacts were made at the same location, the antiresonant region changes for each input output measurement that makes up the total average for the measurement. Therefore, from one measurement location to the next there is no consistency in the measurement and therefore the coherence reflects this.

One additional set of averages was made where the impact point was kept the same but the angle of the impact excitation was allowed to vary during each of the averages. The frequency response (lower trace) and coherence (upper trace) are shown in Figure 3 for this measurement. Similar to the previous case, the coherence is also degraded. There is also a lack of consistency in the antiresonant regions for this measurement.

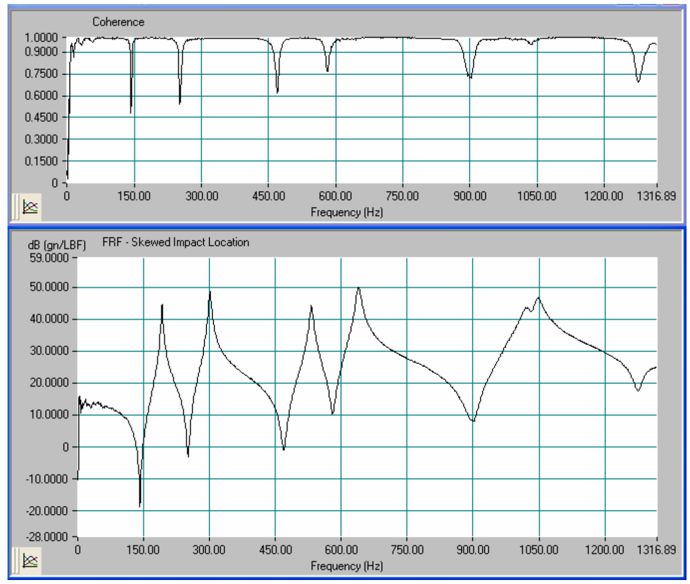

Figure 3 – FRF & Coherence for a Skewed Impact

For both of the cases shown in Figure 2 and 3, the coherence is not nearly as good as the measurement shown in Figure 1. This is due to the inconsistency of the impact location – whether it be not impacting the same location for each measurement or for not maintaining a consistent strike angle for each measurement. Both cases clearly show a degradation of the measurement coherence. A very well controlled, precise impact excitation needs to be maintained for each average that makes up the complete measurement.

These cases are presented here because this is a very common problem during impact testing. This is especially true when the test lasts for a long period of time for measuring many locations. Generally, as time goes on it is very easy to become bored and not maintain the consistent impact during the entire test. This is also very common when the impact locations are at inconvenient locations around, on top or underneath the test structure. When climbing all around the structure (and often in very unnatural positions), it is very easy to not maintain a consistent impact for all averages making up a measurement.

So as a word of caution when impact testing… be very sure to impact the same point, in the same direction, for each of the averages that make up the frequency response function to assure that an overall acceptable coherence is obtained for all measurements.

I hope that this clears up the concerns about possible coherence degradation when impact testing. While there are many more items that could affect coherence, this is one that has an effect. If you have any more questions on modal analysis, just ask me.